GEOTHERMAL DEVELOPMENT AND SOUTHWEST STORAGE BASINS

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That area of the southwest United States that I will talk about includes parts of Arizona, Nevada and Southern California. It is an area wherein the typical structural grain creates a series of debris-filled basins separated by mountain ranges. Here we have crustal distention on a grand scale resulting in deep to shallow rifts and uplifted and faulted elongate crustal blocks.

While these basins differ as to physiographic and geologic detail they also have aspects common to each. First, the basins contain thick deposits of unconsolidated to poorly consolidated debris. Second, the debris is saturated with water close to or at land surface in the center to within a few hundred feet of land surface around the margins where thick fan deposits are present.

With regard to the magnitude of the ground water stored in these basins, I am going to play a numbers game with you. The source of my information is collectively the reports published under the Comprehensive Framework Studies encompassing the whole of the southwest United States. The total amount of water stored in these basins is quantified on one basis or another and usually includes both total porosity and effective porosity of the saturated infilled sediment. Let me also review with you the concepts of safe yield, recoverable storage and usable storage. The safe yield is the amount that can be replenished each year by recharge. The recoverable storage is that water economically available for use after the safe yield has been extracted. It is more or less synonymous with "mining" a ground water reservoir. Usable storage represents the amount of ground water that can be extracted regardless of economics.

There is one important parameter missing here - water quality. Water stored in these basins ranges widely in total dissolved solids. Generally the upper few hundred to 1,000 feet of the sedimentary pile contains water with mineral concentrations that do not exceed Public Health standards for drinking, nor irrigation standards. In the large ground water basins of Arizona the dissolved mineral content increases with depth. In the Imperial Valley we find reversals in the mineral profile wherein lower mineralization is encountered at depths of 5,000 to 6,000 feet with significantly greater mineral concentration in zones above and below this level. This seeming erratic occurrence of ground water concentrations may be due in part to the influence of hydrothermal convective systems involving the movement of low density hot water.

Now for some numbers. In southwestern Arizona, western New Mexico, and southern Nevada, ground water storage to a depth equal to or less than 1,000 feet is estimated to be 1.43 billion acre-feet in alluviated basins. In the south Lahontan subregion of California the total storage capacity in some 50 basins within zones of saturated thickness ranging from 100 to 200 feet is estimated to be in the order of 134.22 million acre-feet. In the Colorado Desert subregion of California, recoverable ground water storage in basins having zones of saturated thicknesses ranging from 100 to 900 feet is estimated to be about 158 million acre-feet in some 45 basins. The total of all these basins is roughly 1.7 billion acre-feet. This is the best ground water estimate that can be made on the basis of available data, which means on the basis of the number and depth of wells drilled in these basins. It represents recoverable storage under present economics.

Let me make another comparison. Take the Imperial Valley, which is considered to be in the Colorado Desert region. The estimate of recoverable ground water in 200 feet of saturated thickness is roughly 15 million acre-feet. If, however, we take a look at the overall geologic dimensions of the Imperial Valley and look at the ground water recovery on the basis of developing the geothermal potential, we start with a preliminary estimate of available storage of 1.1 billion acre-feet having a temperature of 150 c., much of it having a mineral concentration in excess of 20,000 ppm. This is an estimate made by the U. S. Geological Survey and published in its Circular 649. This estimate is adequately qualified as to economic feasibility. I recommend this report to anyone interested in the marriage between the old concepts of ground water exploitation and concepts of heat flow into and within large ground water basins.

So that brings me to heat flow. John Sass and some of his associates with the Geological Survey published a paper in the September 1971 issue of the Journal of Geophysical Research entitled "Heat Flow in the Western United States." These authors were able to confirm that high heat flow was characteristic of the basin and range physiographic province. Heat flow, or the transfer of heat within the earth's crust, is largely by conduction and subordinately by convection. According to Don White of the Geological Survey, the dominant mode of heat flow in the outer crust is by conduction.

In order to quantify heat flow we need two values (1) the temperature gradient and (2) the thermal conductivity of the lithology. The product of the two is heat flow. The preparation of heat flow maps in these inland basins should be done. The Bureau of Reclamation has prepared such a map covering the principal lobe of the mesa anomaly on the east side of Imperial Valley. We drilled some 25 holes to depths ranging from about 300 to 1,400 feet, logged them with gamma ray, resistivity, and self-potential sondes, and measured the temperature gradient to two hundredths of a degree. The method we use equates heat flow with the temperature gradient across the best clay bed in the stratigraphic section penetrated. The best clay bed is defined as that bed composed primarily of poorly-conductive clay minerals and interstitial water with minimum amount of highly conductive quartz in silt size particles. The conductivity of the clays was determined by Jim Combs of the University of California at Riverside, using laboratory methods, and we were able to use his work in our computations of heat flow.

We published a site selection report in June 1973 which sheds further light on the procedures we used. This report is available by writing to the regional director (USBR) in Boulder City. We sited a second well and completed it at a depth of 6,005 feet. It was hotter than our first well at the same depth, suggesting that the technique of heat flow mapping is sound in this hydrogeologic environment.

We are starting an expanded heat flow program to define the full dimensions of the mesa anomaly and to determine the hottest spots within the anomaly. Heat flow mapping in most of the basins of the Southwest appears to be feasible to me. As part of any ground water appraisal, heat flow should be evaluated. Let me remind you that heat flow entails test drilling, logging and temperature measurement. These exploration methods cost money. Moreover, heat flow mapping should be preceded by hydrologic and geophysical surveys, including primarily well and spring canvassing and gravity and resistivity.

The results of these studies may well encourage geothermal development involving generation of power and desalting the produced geothermal fluid. Before undertaking these surveys, I commend to your reading the textbook, "Geothermal Energy, Resources Production and Stimulation," edited by Paul Kruger and Carel Otte and published by the Stanford University Press in 1973.

Now to summarize. I have reviewed information about the amount of water stored in debris-filled basins in a large part of the Southwest. You were given the total figure of 1.7 billion acre-feet of recoverable storage under present economics and water quality standards. I cited Imperial Valley as a debris-filled rift valley that alone contained 1.1 billion acre-feet of usable ground water if we are able to use the energy contained in the heated water primarily to desalt the mineralized water but secondarily to generate power or, depending upon your point of view, primarily to generate power and secondarily to desalt mineralized ground water. Now Imperial Valley may outstrip any of the other alluviated basins as to size but regardless, the meager data show them to be alluviated to greater depth than those at which ground water is now being exploited. In my judgment these crustal features, with their hydrogeologic makeup and occupying an area of the earth's crust where heat flow exceeds the world average, constitute a frontier for water and power development. Conventional ground water development will not get the job done--we have to find the convective systems to tap the energy.

The extent to which today's ground water profession embraces the concept of heat flow and associated methodology will, in my judgment, determine the profession's ultimate contribution in water resources planning in the Southwest.